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How Piston Rod Vibration Signaled a Reciprocating Compressor Problem

The Value of a Monitoring System After Machine Maintenance Has Been Performed

An ethylene gas transmission station provides pipeline booster compression using two (2) single-throw, horizontal reciprocating compressors. Providing sufficient ethylene for production downstream requires that both units must be operated simultaneously. Therefore, the station's two Ingersol-Rand single-throw HHE compressors operate in parallel. Capacity control is provided through a head-end, suction valve, plug-type unloader.

As part of an ongoing predictive maintenance program at this facility, various machine parameters are monitored and trended with online and portable instrumentation. Parameters monitored with online instruments include cylinder valve temperature, main bearing temperature, suction and discharge conditions, and single-plane piston rod vibration and gap. The continuous monitoring system provides alarms on high peak-to-peak piston rod vibration, as well as changes in gap voltage. Parameters monitored periodically include frame vibration, oil condition, and crosshead guide vibration.

It is well known, yet ironic, that machine problems very often occur immediately after maintenance has been performed. Parts may have been installed incorrectly, foreign material may have entered or debris may have been left in the machine, and other problems may have been introduced; thus, in the process of "fixing" the machine, different problems can sometimes be inadvertently introduced. This case history illustrates just such an occurrence and the value that continuous monitoring provides in such situations.

Event

Recently, high peak-to-peak piston rod vibration on one of the compressors was detected. The vibration increased from roughly 4 mils to 6 mils, but then decreased after a few more hours of normal operation. Periodically, the monitor would indicate high vibration that would then return to normal levels, independent of load. Because these readings were neither consistent nor repeatable, plant personnel contacted Bently Nevada to assist in diagnosing the problem.

Additional Instrumentation

To gain more information about the machine operation, additional proximity probes were installed to view piston rod motion on the machine (Figure 1). Supplementing the existing probe (hereafter, referred to as probe A) installed at the pressure packing case at top dead center (TDC), were two additional probes: one mounted at 90 degrees left (as viewed from the compressor crankcase to the cylinder), and the second installed at the scraper packing at bottom dead center (BDC). These will be referred to as probes B and C,

TRANSDUCER INSTALLATION DETAILS SHOWING EXISTING PROBE (A) AND SUPPLEMENTARY TEMPORARY PROBES (B AND C)

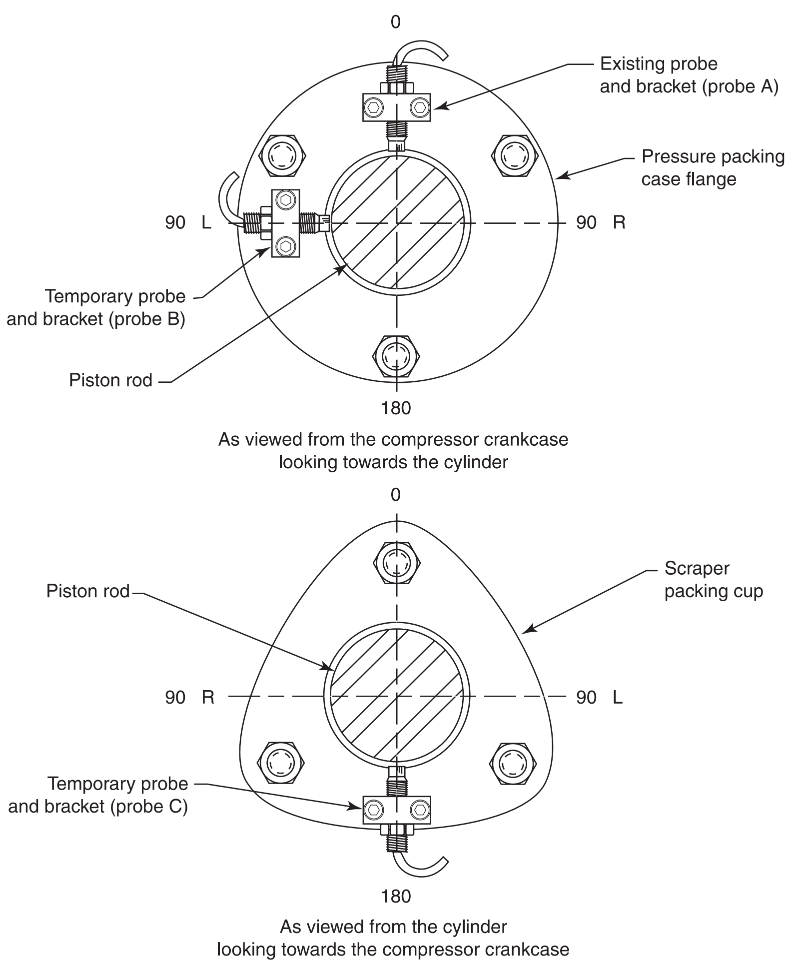

FIGURE 1

respectively. The Keyphasor® transducer triggered at BDC of the cylinder. Cylinder-indicated pressure data was also acquired.

Data Analysis

An ADRE® system collected data simultaneously from the piston rod proximity probes and the cylinder pressure transducer with the machine operating at 50% load for 30 minutes. During this time, peak-to-peak vibration measurements at the existing rod position probe varied from 4 mils to 9 mils (the monitoring system's shut-down alarm of 7 mils had been bypassed). Peak-to-peak vibration from the temporary probe at the scraper packing (probe C) was observed to vary from approximately 12 mils to 15 mils. Figure 2 shows data collected during high vibration (9.40 mils at the existing pressure packing probe). Figure 3 shows data collected approximately 14 minutes later during low vibration (4.38 mils at the existing pressure packing probe). Cylinder load remained constant during this time. As Figures 2c and 3c show, the ac-coupled signal from the pressure transducer does not show significant changes. The same changes in piston rod displacement were observed when the machine was operated under full load. Figure 4 shows the piston rod vibration (3.24 mils) at probe A. Approximately 3 minutes

DATA COLLECTED AT 4:56 PM DURING HIGH-VIBRATION CONDITIONS FROM a) PROBE A, b) PROBE C, AND c) CYLINDER PRESSURE

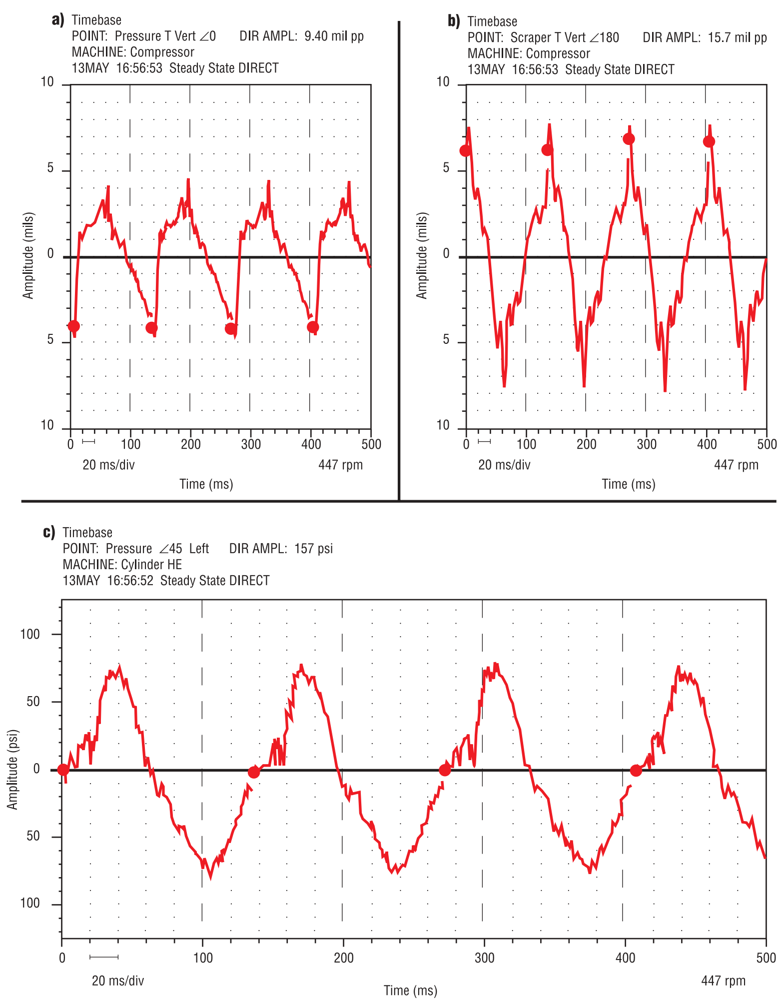

FIGURE 2

later, piston rod vibration at probe A was 7.24 mils (Figure 5). The ac-coupled cylinder pressure is shown in Figures 4c and 5c. Note that cylinder pressure remains essentially unchanged between Figures 4 and 5, yet vibration amplitude more than doubles.

Recommendations

Analysis of the pressure data and vibration data in Figures 4 and 5 revealed that forces acting on the machine did not vary even though the vibration changed. Therefore, stiffness somewhere in the machine was changing. In addition, the piston rod movement was greater at the crosshead than at the packing case. This analysis indicated excessive clearance between the crosshead and crosshead guide, and excessive clearance between the rider band and cylinder bore. These conclusions were forwarded to the customer and the machine was scheduled for shutdown to permit an internal inspection.

Inspection Results

The primary problem was determined to be the piston pressure rings. All four were badly worn and showed signs of damage from foreign material. Figure 6 shows a new ring (top) and a worn ring (bottom). The pressure rings also showed significant wear near the 45-degree angle cut. The sides of the pressure rings had scars from foreign material lodged between the ring and the ring groove.

DATA COLLECTED AT 5:10 PM DURING LOW-VIBRATION CONDITIONS FROM a) PROBE A, b) PROBE C, AND c) CYLINDER PRESSURE

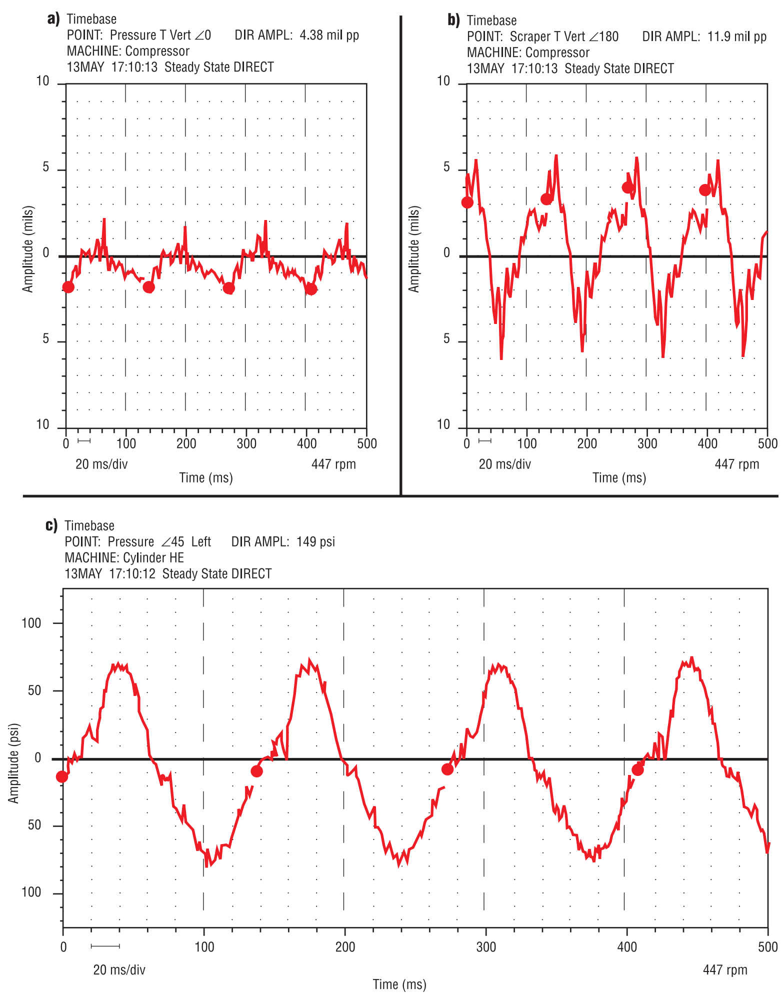

FIGURE 3

DATA COLLECTED AT 6:02 PM DURING FULLY LOADED CONDITIONS FROM a) PROBE A, b) PROBE C, AND c) CYLINDER PRESSURE

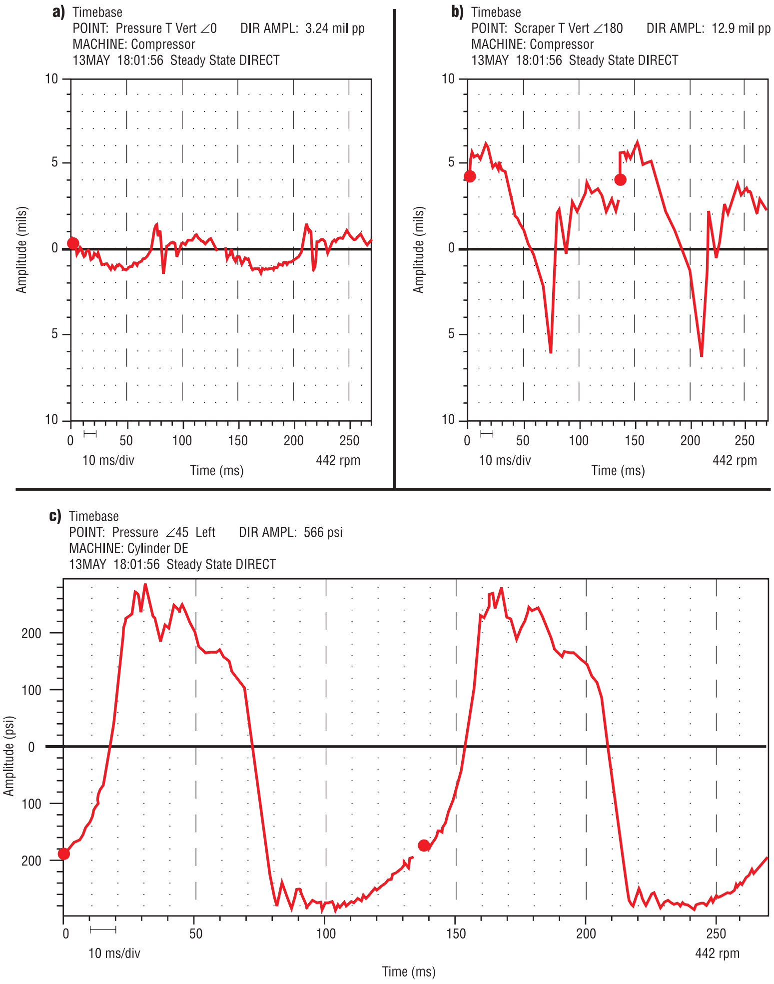

FIGURE 4

In addition to the damaged pressure rings, both rider bands showed deterioration, with scars caused by foreign material lodging between the rider band and piston. Figure 7 shows a rider band and some of the abrasions left by the foreign debris. It is likely that the erratic piston rod vibration readings were caused by debris lodging between the rider bands and piston and later being blown free. Debris trapped between the piston and rider bands reduced the clearance, raised the stiffness, and lowered vibration at the pressure packing case. With no debris between the rider bands and piston, there was more clearance, less stiffness, and the piston rod vibration increased. The source of this debris was also identified. Immediately prior to the change in piston rod vibration, a valve had failed. It was believed that all the spring pieces and valve plates had been cleaned from the cylinder, but, as was now obvious, some debris still remained inside the cylinder.

DATA COLLECTED AT 6:05 PM DURING FULLY LOADED CONDITIONS FROM a) PROBE A, b) PROBE C, AND c) CYLINDER PRESSURE

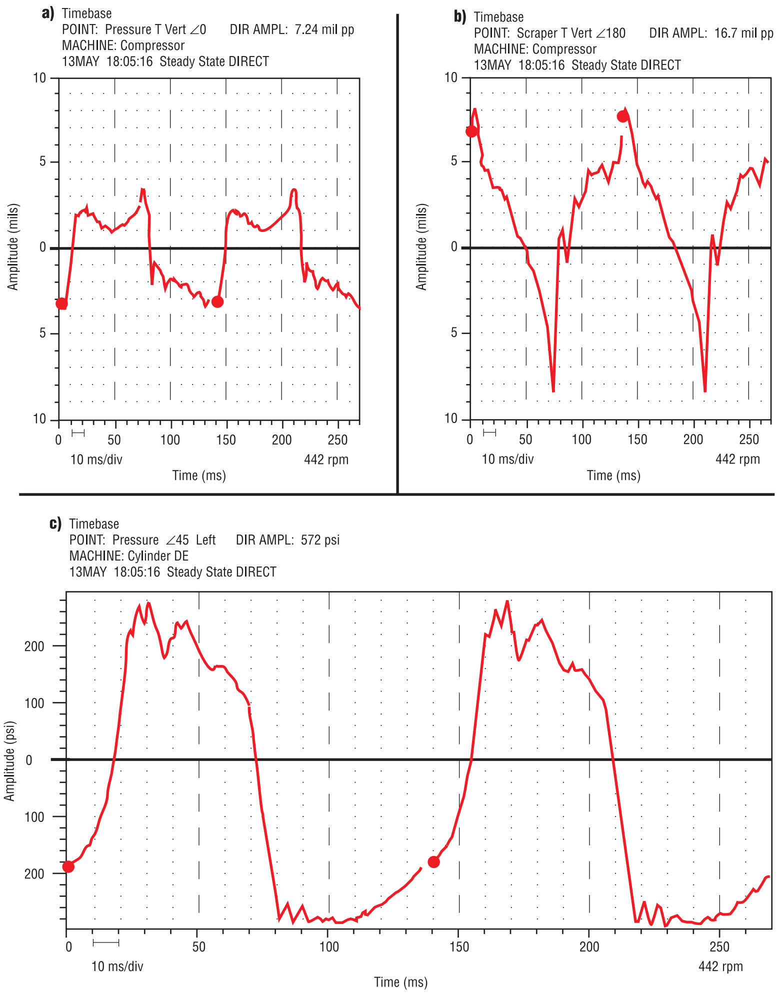

FIGURE 5

PISTON PRESSURE RINGS: NEW RING IS SHOWN ON TOP, WORN RING ON BOTTOM

FIGURE 6

RIDER BAND SHOWING ABRASION CAUSED BY DEBRIS TRAPPED BETWEEN RIDER BAND AND PISTON

FIGURE 7

Crosshead-to-crosshead guide clearance was also checked and found to be outside the limits recommended by the OEM. The excessive clearance was not a result of wear, but stemmed from improperly installed shims.

Conclusions

Figures 8a and 8b show data acquired (approximately 30 minutes apart) from the existing probe after the machine was put back into service. These plots show a stable repeatable waveform and no indication of changes in piston rod displacement or shape.

This case history illustrates the value of continuous monitoring and trending of piston rod vibration as a useful tool in detecting abnormalities in machine operation. As noted, problems can sometimes occur immediately following "corrective" maintenance, when one would normally least expect them. The monitoring system alerted operators to problems, and analysis of subsequently gathered data correctly predicted mechanical changes within the machine rather than process changes or improper machine operating procedures.

PISTON ROD VIBRATION AT PRESSURE PACKING CASING (EXISTING PROBE A) UNDER FULLY LOADED CONDITIONS AFTER REMOVAL OF DEBRIS: DATA COLLECTED AT a) 1:38 PM AND b) 2:08 PM

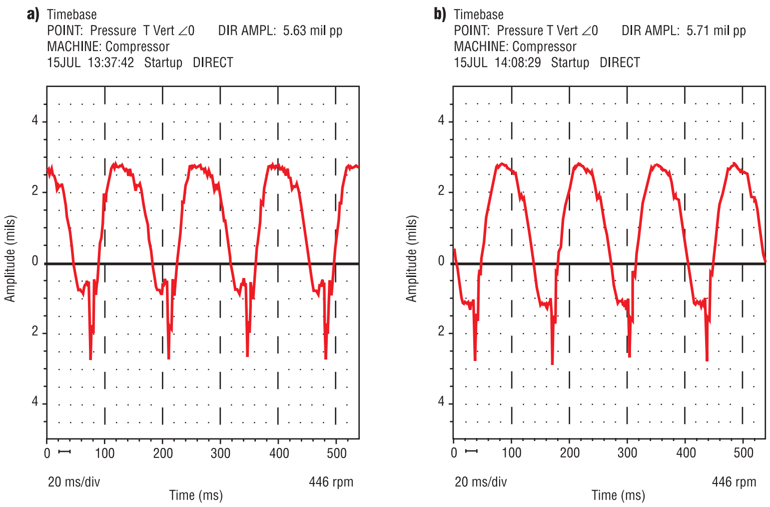

FIGURE 8

Without these vibration measurements there would have been no indication of machinery malfunction until more extensive damage had occurred.

As a result of this experience, the plant's confidence in and reliance upon their monitoring system has increased. Additional parameters are now monitored with an upgraded 3500 Series Machinery Protection system. Data from the 3500 System is brought into a local DCS (Distributed Control System) for trending, making it more readily available to operators. ORBIT